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RESEARCHING RENEWABLE ENERGY SYSTEMS AVAILABLE TO INDIAN COUNTRY

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ABSTRACT

The Department of Energy's Tribal Energy Program in collaboration with Sandia National Laboratories (Sandia) supports a multi-disciplinary team of interns to learn about numerous clean and efficient renewable energy technologies that are readily available for Native American tribes. The field visits through several southwest Native American reservations provided an opportunity for the team to research, examine, and tour tribal on- and off-grid photovoltaic (PV) systems, PV/wind hybrid systems, a micro-grid hybrid renewable energy system development, a large-scale wind farm, and Sandia's and National Renewable Energy Laboratory's facilities. The content of this paper will highlight each field visit to the various renewable energy (RE) systems during the summer internship. The field visits allowed the interns to meet with the people on Native American reservations who benefit from renewable energy projects and learn how those projects affect their people. Field visits of RE installations were documented which support the Tribal Energy Program objectives: to promote tribal energy sufficiency,

[1] Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC-04-94AL85000.

economic development, and employment on tribal lands through the use of renewable energy and energy efficiency technologies.[2]

RESEARCH METHODS

The summer interns utilized a variety of research methods in order to acquire a thorough understanding of renewable energy with a focus in photovoltaic and wind technologies. The multi-disciplinary team of university interns included: an undergraduate student in Electrical and Computer Engineering, a graduate student in business finance, an undergraduate student in Applied Indigenous Studies, and a graduate student in American Indian Studies. Each intern offered a unique perspective. The primary source of obtaining information stemmed from publications of Sandia National Laboratories' Solar and Wind Technology Divisions and the Navajo Tribal Utility Authority's (NTUA) Solar Program. Sandia's publications that were used included, "The Solar Way: Photovoltaics on Indian Lands, Solar Photovoltaics for Development Applications," and numerous Sandia documents. Other documents referenced were the NTUA's PV Operations and Maintenance (O&M) Manuals for Phases I and II; Specifications of the PV Phases I and II; PV Owners Manual; and PV meeting and training handouts.

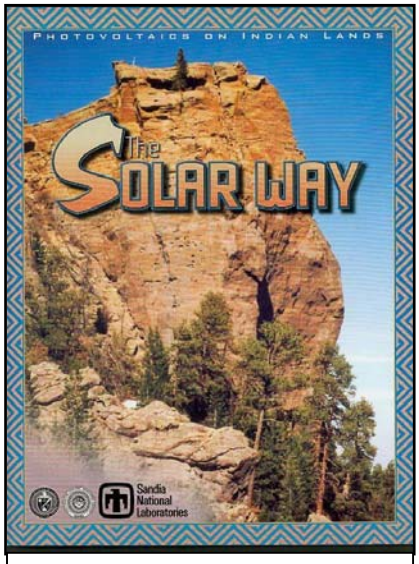

Figure 1: Photovoltaics on Indian Lands- The Solar Way

A secondary research method was direct interaction with NTUA's Solar Program personnel, including the renewable energy specialist, electricians, and customer service

[2] "Renewable Energy Development on Tribal Lands." US Department of Energy. 2004.

representatives. The one-on-one dialogue allowed the interns to gather valuable information and was used to complete their respective summer projects.

Additionally, the interns conducted field visits to renewable energy installations sites where they analyzed different technologies in order to thoroughly document their projects. The documentation process during the field installation visits was extremely valuable; sustainability of programs includes extensive documentation of processes and RE information. While observing the field installations, in-depth discussions with local personnel occurred. For example, a discussion of the updated Bi-Annual maintenance procedure was addressed and clarified with NTUA, which allowed an intern to appropriately revise a process flowchart.

ON-GRID PHOTOVOLTAIC INSTALLATION

Figure 2: Sandia interns mounting the PV modules onto the sun tracker.

The interns participated in a weeklong photovoltaic design and installation course at the Crownpoint Institute of Technology (CIT), a tribal college. The experience provided a valuable set of technical information and a foundation of photovoltaic understanding. In the process of building the two PV arrays, the interns learned about

grounding, sizing each wire according to the National Electric Code, the tracking component of a system, and the Balance of the System (inverter, batteries, charge controllers). During the hands-on training, the participants were divided into three groups (1) building the frames, mounting and wiring the arrays; (2) mounting a box onto the poles to house wire-connects, grounding and wiring the two poles that would support the arrays; and (3) installing the direct current and alternating current disconnects, Sunny Boy inverter, and amp-hour meter. The interns helped all three groups in order to gain an overall understanding of how each group completed their respective duties and how the Balance of the System components work together.

Specifically, the first group built the frames and wired a section of the panels to make an array; the second group bent and cut protective metal that connects the direct current disconnect to the inverter; and the third group pulled the grounding wire. The interns participated in this work when appropriate. There were many opportunities for the interns to ask questions throughout the installation process. The 1880 Watt PV system installed was grid tied and had no energy storage; therefore, none of the interns had any physical experience with a battery bank. In retrospect, the CIT Alternative Energy Program 101 course lecture and the hands-on project was an invaluable learning experience.

THE NAVAJO TRIBAL UTILITY AUTHORITY AND DEMOGRAPHICS OF THE NAVAJO NATION

The unique collaboration between Sandia National Laboratories and the Navajo Tribal Utility Authority, an enterprise of the Navajo Nation stems from the government-to-government relationship. In 2000, the signed Memorandum of Understanding between

Sandia, the US Department of Energy (DOE), and the Navajo Nation authorized the technology transfer that benefits all parties. NTUA is a non-profit rural utility service that currently serves approximately 32,500 electric customers; 28,000 water customers; 12,000 wastewater customers; and 7,000 natural gas customers.[3] NTUA offices are strategically located within five districts to regionally support their utility operations and for customer service.

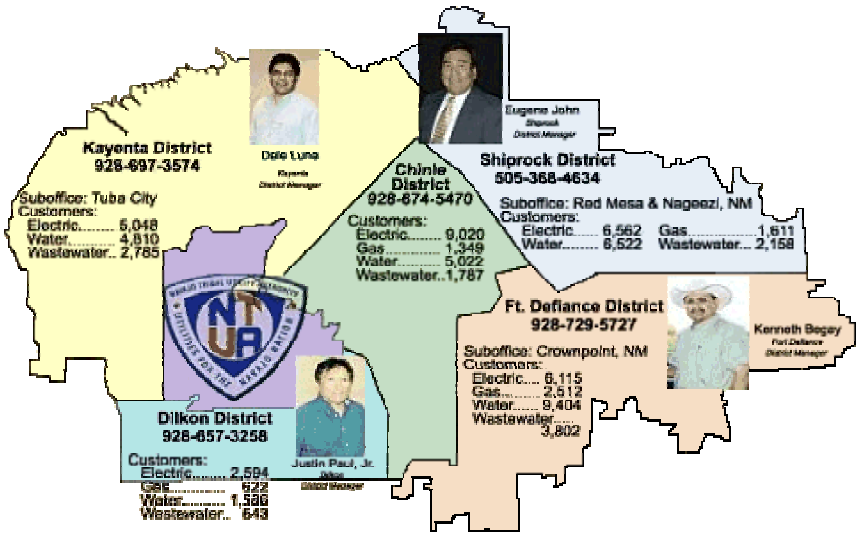

Figure 3: Map of NTUA service districts.[4]

The Navajo Nation has 298,215 enrolled tribal members residing throughout the United States. Of the total enrollment number, there are 152,200 Navajos residing within the 27,000 square mile reservation.[5] The tribal boundary extends into areas of northwestern New Mexico, northeastern Arizona, southeastern Utah, and southwestern Colorado.

[3] Interview with Ken Craig, NTUA Manager of the Engineering Division, 7/8/04.
[4] See NTUA website at, http:\\www.ntua.com
[5] "Sustainable Hybrid System Deployment with the Navajo Tribal Utility Authority" by S. Begay-Campbell.

DEMOGRAPHICS OF THE HOPI TRIBE

The Hopi Tribe is located in northeastern Arizona with approximately one million acres of tribal land. The enrollment is approximately 8,000 tribal members. The Hopi reservation received electrical power by Arizona Public Service by way of grid extensions from Holbrook through the Navajo Nation and onto the Hopi reservation.[6] Since the mid 1980's NativeSUN, a Hopi non-profit PV company has sold and installed about 100 PV systems to residential homes. A significant difference form NTUA's Solar Program is that the Hopi homeowners perform the maintenance of their systems.

OFF-GRID PV SYSTEMS

Figure 4: NTUA's PV and small wind hybrid unit.

The four days of the RE installation tour throughout the Navajo Nation and Hopi Tribe demonstrated each tribe's dedication to incorporate the latest PV and small wind turbine technology which can then provide power to their customers. The interns were able to learn about the history of the PV units that were designed to supply the customers' needs and accommodate the natural environment.

[6] Phone Interview with Gerald Calnimptewa, Chief of Staff to the Hopi Chairman.

The meeting at the Navajo Tribal Utility Authority headquarters with Larry Ahasteen, the Renewable Energy Specialist was full of information gathering. Our meeting at the NTUA Kayenta sub-office with Melissa Parrish, Electrical Apprentice, offered an electrician's perspective on the operation and maintenance of the PV units. Our field visits allowed us to examine the 880-Watt PV and small wind turbine hybrid units at Luther Deswood's home in Cane Valley, Arizona and a similar residential unit at Carmelita Blackwater's residence in Denehostso, Arizona.

Figure 5: NativeSUN installed a PV residential unit on the Hopi reservation.

The visits to a Third Mesa Hotevilla village located on the Hopi reservation in Arizona allowed the interns to research PV systems at the homes of Letha Masayesva and Rosie Onsae, which systems provided enough electricity for their basic needs: lighting, sewing machine, and occasionally watching the television. The interns were impressed with the two elderly Hopi homeowners' maintenance of their PV systems.

Once the PV technology was demonstrated to produce electricity in the Hopi residential villages, Hopi business owners learned how to incorporate PV and passive solar into their business operations. The interns visited two Hopi cultural gift shops. One of the shops was electrified by a small PV unit, which powered low energy halogen bulbs

used to highlight the arts and crafts and a radio that played Native American music. The shop employee(s) were educated in energy conservation and only turned on their lights and radio when customers walked into the shop and turned them off as soon as the customers left.

The second gift shop utilized passive solar in which numerous large windows allowed the natural sunlight to enter and showcase their products. The two alternative uses of energy worked best for their respective environment and their needs.

UPDATING NTUA's PV OPERATION & MANTENANCE MANUAL

Figure 6: NTUA electricians and Sandia interns performing O&M.

In 1999, the NTUA received the first non-hydro loan from United States Department of Agriculture (USDA) Rural Utility Service (RUS) for $4.8 million, a portion of which was used to expand their existing Solar Program.[7] After the implementation and operation of two hundred 640 Watt PV systems, NTUA published a comprehensive photovoltaic operation and maintenance (O&M) manual in 2001. The publication was submitted to the USDA Rural Utilities Services to fulfill their loan

[7] "Sustainable Hybrid System Deployment with the Navajo Tribal Utility Authority" by Sandra Begay-Campbell, 2003.

requirements. Through the authorized Navajo Nation Electrification Demonstration Program, the DOE Albuquerque Operations Office issued a cooperative agreement to NTUA in 2002, providing $800,000 to support the initial phase of the Navajo Electrification Solar Project. One year later, the DOE awarded NTUA with an additional $1,150,000 to procure 63 more hybrid units (Phase II). Public Law 106-511, Section 602, Navajo Nation Electrification Demonstration Program authorize both cooperative agreements.

The NTUA Electric Energy (Solar Energy), Engineering, and Technical Services Division and Sandia National Laboratories both recognized the need to update the O&M manual to include all of the RE systems. The primary use for updating the O&M is to provide the NTUA with a comprehensive compilation of PV technical information, specifically 880-Watt PV Phase I & II systems. Once the O&M manual is updated and published, NTUA PV electricians will be able to quickly reference the information needed to complete their project assignments safely and effectively. More importantly, a significant reason to update the O&M manual is the issue of sustainability for NTUA's Solar Program. As the interns research current PV data and incorporate new information into existing sections of the 2001 published O&M manual, the documentation process strengthens the entire Solar Program's operation and sustainability.

As an outcome of the 2000 MOU, Sandia National Laboratories provides technical assistance and training to NTUA electricians who work in the Solar Program. One example of how Sandia offers technical assistance to NTUA is by coordinating research to be produced by Sandia summer interns. The interns from the Sandia summer internship program contribute to the sustainability of NTUA's Solar Program by

documenting unpublished PV project information for an upcoming NTUA PV Operation and Maintenance Manual.

The multi-disciplinary team of interns worked collaboratively to incorporate the history and explanation of why NTUA has upgraded their PV systems, create a new section of the revised "Troubleshooting Flowchart" and the "Bi-Annual PV System Flowchart" with a written narrative explanation of the process. Technical information will be combined (i.e., updated flowcharts) with historical (i.e., case study) information into the appropriate sections of the O&M Manual.

RECOMMENDATIONS FOR NTUA's PV OPERATION AND MAINTENANCE MANUAL

As the interns updated the O&M manual they are able to make recommendations that they believe are pertinent to include in the revised O&M manual. The recommendations highlight areas to be considered when updating the O&M manual. This list was developed as a result of field visits and interviews with NTUA's Solar Program personnel, which are listed below.

- Incorporate the 880 Watt PV and wind hybrid Phase I historical introduction, grant agreements, tariff structure, proposal and bids, manufacturer and integrators, and the performance report;
- Incorporate the 880 Watt PV and propane generator historical introduction, grant agreements, tariff structure, proposal and bids, manufacturer and integrators, and the performance report;
- Incorporate the 880 Watt PV and wind hybrid Phase II historical introduction, grant agreements, tariff structure, proposal and bids, manufacturer and integrators, and the performance report;
- Create a new section regarding new technologies such as Global Positioning System (GPS) charts;
- Create a new section regarding "Problems and Solutions;" and

The following recommendations focused more on the practical operation of maintaining PV and PV/wind hybrids. Benjamin Mar, Sandia summer intern, identified recommendations that resulted from interacting with NTUA customer service representatives and electricians, as well as observations during field visits, which are listed below.[8]

- Insure that during PV and hybrid systems installation, the PV array is Not shaded. A PV array with direct shading can dramatically lower the electricity generation;

- Have an open purchase order for distilled water. An open purchase order for distilled water would allow electricians to buy the distilled water to save numerous O&M visits in one trip;

- Have a surplus of PV equipment for the appropriate system that is going to be maintained on the electricians' truck. By having spare equipment on the truck, electricians would be able to replace malfunctioning equipment during the initial visit instead of making another trip;

- Have all potential PV customers view the educational video, "Power from the Sun", before enrolling into NTUA's Solar Program. The video covers the basic information that is sometimes missed in a brief conversation when a potential customer visits a district office for ten minutes to seek information; and

- Have all customer service representatives from each district, observe an installation process to see how the PV and hybrid systems are installed. This would allow for better communication between the customer service representatives and the electricians. Both of them would be able to perform the customer education in a coordinated fashion.

NAVAJO TRADITIONAL AND SOCIAL PERSPECTIVES REGARDING PV

The NTUA adheres to the Navajo cultural issues, which pertained to natural resources of the sun and wind; while acknowledging how to work harmoniously with both forces. Mr. Ahasteen, Renewable Energy Specialist for NTUA, mentioned two

[8] "Navajo Tribal Utility Authority: Photovoltaic Hybrid Operation and Maintenance Process for A Sustainable Program" by Benjamin Mar. 2004.

fundamental concepts of "respect and reverence" for the natural environmental phenomena. For example, a Navajo legend explains the importance of a solar eclipse and how it affects the Diné (Navajo People). Another traditional example would be the sacredness of giving prayer offerings of corn pollen near wind trails. When viewing the world in a Navajo perspective, the Navajo People understand the reasons why Navajos do (or not do) certain things at certain times of the year. The interns believe that NTUA acknowledges and respects the customers' choice of accepting a PV system or adversely choosing not to adapt to the alternative form of gaining electric power.

The NTUA's PV customers reside in extremely rural and isolated locations throughout the reservation. Sandia Intern Jennifer Coots explains the reality of NTUA's PV customers.

> The choice to live in such a remote location is related in many ways to the Navajo culture. Traditionally, Navajo people were herders and lived in small family clusters. Contemporary Navajos choose to live on their ancestral lands in remote locations because they have deep ties to the land itself. Elders who told stories relating to the land may have raised children. A Navajo may know where a particular herb used for ceremonies grows on a mountainside.[9]

The Navajo philosophy emphasizes the importance of improving, planning, and protecting the future of their children. One aspect of improving the Navajo youth is to provide the basic living needs, specifically residential electrical lighting. According to the 2002 NNEDP Progress Report, a PV customer's needs were met.

> Her [Betty Simpson] children had to go to a neighbor's home just to do [academic] homework. They relied on flashlights for night lighting, which also became an added expense. She explains that the kids now do homework at home giving more time in the evening to spend together as a family.

[9] "A Decade of Changes to an Alternative Power Source For a Rural Utility," by Jennifer Coots. 2004.

MICRO-GRID HYBRID RENEWABLE ENERGY POWER SYSTEM PROJECT

Figure 7: Propane generator will be used as a back-up energy source for the micro-grid hybrid system.

In 2002, the Ramona Band of Cahuilla Mission Indians located near Anza, California were awarded a Department of Energy Tribal Energy Program grant to implement a sustainable renewable energy development project.[10] The interns learned how Native American tribes might have the opportunity to work with funding from two or more US Federal Agencies' grants and loans on projects or one specific section of the project. As a result of this type of multi-agency funding, a hospitality ecotourism cultural resort development has been funded from the DOE grant, a Housing and Urban Development Community Development Block Grant, and a USDA Rural Development grant.

The field visit to the Ramona Band of Cahuilla Mission Indians was another eye opening learning experience that focused on their Ecotourism Cultural Resort which will be powered entirely off-grid by an anticipated 65-80 kW a day PV hybrid system. The

[10] Department of Energy-Tribal Energy Program website. http://www.eere.energy.gov/tribalenergy/projects/fy02_cahuilla.html/. 2004.

design and development of incorporating PV, small wind, and a propane generator hybrid into the blueprint of a Native American tribal economic development project is what differentiates this visit from previous field installation visits. The entire reservation is off-grid and is "land-locked" between the Bureau of Land Management and US Forest Service lands which surround the reservation, resulting in no electricity, water, phone service, or roads. In summary, it is important to acknowledge how various tribes' demonstrate their sovereignty and culture, while exploring possible avenues to generate tribal economic development. The multi-discipline interns were grateful to have observed and experienced another tribe's development of incorporating renewable energy technology into their way of life.

WIND ENERGY TECHNOLOGIES

Figure 8: Interns at the Wind Energy Center.

The one-day tour to the new Florida Power and Light (FPL) commercial-scale wind energy center in House, New Mexico was a tremendous introduction to wind energy. The basic statistics of the wind farm are: tower height is 213 feet tall with three

aeronautically designed fiberglass blades that are 110 feet long; there are 136 1.5 megawatt turbines that can produce enough electricity to electrify approximately 94,000 homes from a total of 204 megawatts; "the optimum wind speed is between 25-55 mph[11];" three engines/motors are located in the nacelle, which houses generator, gear box, and weighs 120,000 lbs.; and a SCADA computer system is used to monitor each wind turbine simultaneously. The interns learned that the blades are pushed by the wind and the movement of the blades is the power source for the generators that are located at the base of the blades. As a result electricity is created and is transferred into a substation and later feeds into an existing electrical grid. Public Service Company of New Mexico is the customer that buys the electricity generated from the wind farm and electrifies residents in New Mexico. The experience helped in understanding how Native American tribes could incorporate wind technology to create energy and improve the quality of life for their people.

The Navajo Nation and NTUA have also researched high wind areas within the reservation. An anemometer is used to collect exact wind speeds for possible future wind development. Today, NTUA has approximately 100 PV/ small wind turbine stand-alone hybrid systems servicing remote homesteads. The Phase I wind turbines specifications are AIRX 400-24 wind turbine by Southwest Wind Power, rated -24Vdc, 400 Watts @ 28mph.[12] The Phase II wind turbines specifications include with each system is a Southwest Wind Power AIRX-24 wind turbine rated for 24VDC-400 Watts @ 28mph and a PWM battery charge controller, over speed control, cast aluminum housing and supplied with a 30', 1-1/2" conduit, #8-3 x100' outdoor cable with a 3 year warranty.[13]

[11] FPL handout…
[12] Technical Design Submittal for PV/Wind hybrid by SunWize Technologies. 2002.
[13] Installation Operation & Maintenance Manual by SunWize Technologies. 2004.

DISTRIBUTED ENERGY RESOURCES

The interns attended the Federal Energy Management Program (FEMP), Distributed Energy (DER) Resources hands-on training conducted at Sandia's Distributed Energy Technologies Laboratory. The objective of attending the training was to learn and become familiar with DER technologies. Sandia's research scientists presented on technologies of: combine heat and power, photovoltaic systems, and Co-Generation Plants. Additional presenters from the National Renewable Energy Laboratory, US Marine Corps, US Combine Heat and Power Association, and Wagner Power Systems all of whom discussed the DER technologies of: financing and economic evaluations; security; and the operations and maintenance of fuel cells, micro turbines, PV systems, wind, hybrids, and reciprocating engine-generators.

CO-GENERATION FACILITY

The second day of the Federal Energy Management Program Training scheduled a tour of the only New Mexico Co-generation facility, the City of Albuquerque Water Treatment Co-generation Plant. Co-generation refers to the process of producing electricity and a beneficial thermal product such as steam or hot water.[14] The incorporation of combine heat and power allows a system to reach greater than 70% of its energy efficiency. Thermal energy in the micro turbine exhaust gas can be transferred to pre-heat hot water in a heat exchanger.[15] The captured heat from the 2.5-megawatt caterpillar engine is transferred to the digester to assist in the decomposition of wastewater.

[14] "DER Technologies and Features" handout, presented by Tom Byrd. June 2, 2004.
[15] "DER Technologies and Features" handout, presented by Tom Byrd. June 2, 2004

NATIONAL RENEWABLE ENERGY LABORATORY

Figure 9: Sandia interns toured the Solar Energy Research Facility at NREL.

The National Renewable Energy Laboratory (NREL) is a partner in the DOE Tribal Energy Program. The DOE Tribal Energy Program sponsored a weeklong training, Tribal College: Teach-the-Teachers workshop in Golden, Colorado. The workshop objective was to educate tribal college instructors about RE technologies with the goal of incorporating RE information into their course curriculum. As a result of Native American tribes' interest in resource assessment and renewable energy, tribal representatives attended the training.

The five main technologies discussed include: solar electric, wind power, biomass, geothermal, and energy efficient buildings. In addition to the lectures and literature, site visits to the Solar Energy Research Facility, National Wind Technology Center, Solar Radiation Research Laboratory, and PV Outdoor Test Facility were instrumental in understanding each technology. The interns understood the different energy technologies that tribal college instructors and Native American tribes can attain

and develop. Another aspect learned throughout the week, was how the Tribal Energy Program works in collaboration with Sandia, NREL, and DOE Office of Energy Efficiency and Renewable Energy.

CONCLUSION

The collaboration among the DOE Tribal Energy Program, Sandia, and the Navajo Tribal Utility Authority support renewable energy development. The interns learned a wealth of information about numerous clean and efficient renewable energy technologies that are available for Native American tribes according to their natural environmental resource(s). The installation field visits throughout Indian Country provided an opportunity for the team to research and interact with "real installation projects, real people, and witnessing real energy produced."

This internship allowed me to research renewable energy technologies, which are used on tribal reservations and this research can be incorporated into my University of Arizona American Indian Studies Graduate Program thesis. If I choose a thesis topic relating to PV and small wind hybrid systems or other renewable energy technology available in Indian Country, my research can be refer to the information and experience gained this summer. The Tribal Energy Program's summer internship was an invaluable opportunity for me and I understand that renewable energy technologies are a viable option for tribal and US energy generation.